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EFFECTS OF ROOT AND FOLIAR TREATMENTS OF CARROT PLANTS WITH LEAD AND CADMIUM ON THE GROWTH , UPTAKE AND THE DISTRIBUTION OF UPTAKE OF METALS IN TREATED PLANTS

Key words: Toxicity , growth, uptake, carrots, cadmium, lead, root-treatment, foliar-tratment, uptake distribution, roots, shoots

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ABSTRACT

Toxicity of cadmium and lead on the growth of carrot plants has been studied. Cadmium has been found to be more toxic than lead especially on the shoots of carrot plants.

Foliar treatment has been compared with root-treatment for the two elements on carrots and on their roots and shoots.

Concentrations and total contents of lead and cadmium in whole plant, in roots and in shoots have been determined for treated carrot plants and compared in root-treatment with foliar-treatment. Explanations have been suggested whenever possible to illucidate the results obtained.

Percentages of the metals taken by plants from the whole amounts of metal added during treatment have been calculated and related to type of metal used, concentration of metal in solutions used for treatment and the way of treatment.

INTRODUCTION

Toxic metals can be transferred and concentrated into plant tissues from soil, irrigation water, or from rain water deposition. These toxic metals may have damaging effects on the plant itself and may become a health hazard to man or animal.

Several studies have appeared in the literature investigating the effects of treatment with toxic metals on growth of plants and on the value and distribution of the uptake of metals in the various parts of plants. It has been found that no one rule can be generalized to describe the effects of toxic metals on plants. On the contrary, it seems as if every metal and plant has its own system of interaction, which depends on several factors such as type of

soil, properties of soil, growth conditions, and presence of other ions.

Lead and cadmium are among the most interesting metals for environmental studies including their effects on plant and their accumulation in plant tissues. Several studies have appeared in the literature studying the effect of these metals on plants; few of these studies were on carrots among other species of vegetables (1 - 3). The aim of this paper is to study the effect of treatment with cadmium and lead on the growth of carrots and on the uptake of metals in the shoots and roots of plants. Also we aim to compare between the toxicities of lead and cadmium on plant growth. Comparison between root-treatment and foliar-treatment of plants has shown that foliar-treatment with metal ions is more effective on plant growth than root-treatment (4, 5). We aim in this paper also to compare between these two types of treatment using lead and cadmium on carrot plants and on roots and shoots of the treated plants.

EXPERIMENTAL

The soil used in this study was provided by a local nursery and consisted of 1:2 of sand and brown soil, respectively. Three and half kilograms of mixed soil were taken in plastic pots. In each pot three seeds of carrots (Daucus carota L., variety sativa DC.) were germinated under green-house conditions.

When the first true leaves had appeared only one plant was left in each pot.

Treatment with metal ions started after 2 weeks and was repeated once a week for 12 weeks till the complete growth of plants. Plants were irrigated with tap water (200 ml) once a week and with a nutrient solution once every two weeks during the whole period of growth. Three plants were treated with each concentration of metal ion studied here.

After complete growth, plants were taken, washed with distilled water and then each part of plant was taken separately. Plants were then dried in an oven at 90° c, ground and ashed at 550°c for 6 hours. The ash of each part was then put in a labled plastic bag for the chemical analysis.

A known weight of the ash sample was treated with 2 ml of conc. HNO_3 and digested under pressure at 170° c After that the total volume was made up to 15 ml and all samples were analysed for lead or cadmium using a Perkin-Elmer 5100 Graphite Furnace Atomic Absorption Spectrometer equipped with HGA-7700 Professional Computer. The calibration method used was the standard addition method (3 additions). A matrix modifier of palladium nitrate was applied for the analysis of cadmium. The mean of three determinations was taken for each concentration with a relative standard deviation of <10 %. The average of the concentations of the three treated plants was taken for each metal concentration used.

More details concerning soil characteristics,nutrient solution and the analytical programmes used can be found in another paper(5).

RESULTS AND DISCUSSION

Effect of Treatment with Cadmium and Lead on the Growth of Carrots

Toxicity of cadmium and lead on the growth of carrots was visible. Shoots of plants had noticeable and gradual stunted-growth, small leaves and chlorosis. These symptoms were more obvious in plants treated with cadmium than in plants treated with lead. Also, these symptoms were more obvious in foliar-treated plants than in root - treated plants. The reductions in dry weight of carrot plants as a result of their treatment with lead and cadmium are shown in Tables 1 and 2 for plants treated with lead and cadmium, respectively.

Results of Table 1 show that root-treatment with 0.6-18.8 ppm lead solutions (200 ml batches repeated for 12 times over the whole period of growth) resulted in 24 - 62 % reduction in weight of plant, 20 - 60% reduction in weight of shoots and 27-77% reduction in weight of roots. The higher the concentration of lead in solution used in treatment the higher was its effect on growth. The results of Table 1 show also that foliar-treatment with 0.6-18.8 ppm lead solutins (50 ml batches repeated for 12 times over the whole period of

Table (1)

Effect of Treatment with Lead on the Growth of Carrot Plants

Pb conc. in solutions used for treatment (ppm)	Roots dry weight (g)	Roots reduction in weight (%)	Shoots dry weight (g)	Shoots reduction in weight (%)	Whole plant dry weight (g)	Whole plant reduction in weight (%)
Root-Treatment (200ml x 12 times)						
0.0	1.241	0.0	0.996	0.0	2.237	0.0
0.6	0.906	26.9	0.799	19.8	1.705	23.8
1.9	0.821	33.8	0.619	37.8	1.440	35.6
3.1	0.838	32.5	0.801	19.6	1.639	26.7
6.3	0.675	44.8	0.614	38.4	1.289	42.4
9.4	0.391	68.5	0.491	50.7	0.882	61.5
12.5	0.320	74.2	0.402	59.6	0.722	67.7
18.8	0.286	76.9	0.560	43.8	0.846	62.2
Foliar-Treatment (50ml x 12 times)						
0.0	1.241	0.0	0.996	0.0	2.237	0.0
0.6	1.148	7.5	0.951	4.5	2.098	6.2
1.9	0.988	20.4	0.800	19.7	1.788	20.1
3.1	0.888	28.4	0.692	30.5	1.580	29.4
6.3	0.718	42.1	0.628	36.9	1.346	39.8
9.4	0.777	37.4	0.490	50.8	1.267	43.4
12.5	0.637	48.7	0.501	49.7	1.138	49.1
18.8	0.621	50.0	0.209	79.0	0.833	62.8

growth) resulted in weight reduction of 6-63% of whole plant, 5-80% of shoots and 8-50 % of roots. The effect on growth increased also with the increase of concentration of lead in solutions used for the treatment of plants.

Comparison of the two ways of treatment together indicated that foliar-treatment was more effective on the growth of carrots than root-treatment. The amount of lead added using one concentration in foliar-treatment was one fourth the amount added using the same concentration in root-treatment but resulted in almost the same reduction in weight of plant (c f. Table 1). Root-treatment with lead affected the growth of roots more than shoots but the foliar-treatment affected the growth of shoots more than roots.

Results of Table 2 indicated that using cadmium for treatment of carrots resulted in a high effect on the plant growth (as indicated by the dry weight reduction) and this effect increased with the increase of cadmuim concentration in solutions used for either root-treatment or foliar-treatment. The weight reduction resulting from treatment with 0.4-10 9ppm cadmium solutions amounted to ~14-71% from the whole plant, ~18-79% from the shoots and ~11-64% from the roots of the root treated plants The weight reduction in case of foliar-treatment using the same concentrations but one fourth the amounts of cadmium used in root-treatment amounted to ~6.0-73% from the whole plants, ~5-80% from the shoots and 7-68% from the roots of the foliar-treated plants. These results indicated a higher effect of foliar-treatment with

Table(2)
Effect of Treatment with Cadmium on the Growth of Carrot Plants

Cd conc. in solutions used for treatment (ppm)	Roots dry weight (g)	Roots reduction in weight(%)	Shoots dry weight (g)	Shoots reduction in weight(%)	Whole plant dry weight (g)	Whole plant reduction in weight(%)
Root-Treatment (200ml x 12 times)						
0.0	1.241	0.0	0.996	0.0	2.237	0.0
0.4	1.110	10.6	0.820	17.7	1.930	13.7
1.1	1.030	17.0	0.799	19.8	1.779	20.5
1.8	0.968	22.0	0.670	32.7	1.638	26.8
3.6	0.716	42.3	0.660	33.7	1.376	38.5
5.5	0.526	57.6	0.522	47.6	1.048	53.2
7.3	0.511	58.8	0.302	69.7	0.813	63.7
10.9	0.450	63.7	0.209	79.0	0.659	70.5
Foliar-Treatment (50ml x 12 times)						
0.0	1.241	0.0	0.996	0.0	2.237	0.0
0.4	1.149	7.4	0.945	5.1	2.094	6.4
1.1	1.159	6.6	0.732	26.5	1.891	15.5
1.8	0.972	21.7	0.620	37.8	1.592	28.8
3.6	0.919	25.9	0.538	46.0	1.457	34.9
5.5	0.577	53.5	0.487	51.1	1.064	52.4
7.3	0.460	62.9	0.322	67.7	0.784	65.0
10.9	0.403	67.5	0.201	79.8	0.604	73.0

Table (3)

Concentrations Causing 50% Weight Reduction

	Lead (ppm)		Cadmium (ppm)	
Part of plant	Root - treatment	Foliar- treatment	Root - treatment	Foliar - treatment
Roots	6.9	13.2	6.0	5.6
Shoots	9.5	9.2	5.3	4.5
Whole plant	7.2	12.0	5.4	5.2

cadmium than the root-treatment of carrots on the growth of the whole plant as well as on the growth of both roots and shoots. The effect of both ways of treatment was higher on shoots than on roots.

In order to compare the toxicities of lead and cadmium on the growth of carrot plants and on their roots and shoots the concentrations causing 50% inhibition of growth were calculated from the linear parts of the figures relating the weight reduction versus the concentration of metal ion in solutions used for the treatment of plant. The results of these calculations are presented in Table 3 From the results of this table it was obvious that cadmium had higher toxicity on the growth of plants and on their roots and shoots than lead. This difference in toxicity was more obvious in the case of foliar-treatment than in the case of root-treatment of plants. This difference in toxicity was also more obvious on shoots than on roots of the treated plants. Table 3 showed also the higher effect of foliar-treatment over root

treatment (comparing amounts of metal used in treatment rather than concentrations).The high effect of foliar-treatment was more obvious in the case of cadmium than in the case of lead.

Another interesting point was observed when comparing lead with cadmium toxicities on growth and this was the high effect of cadmium on shoots in both types of treatment while lead was more effective on the roots of the root-treated plants and on the shoots of the foliar-treated plants. This might be an indication of the high mobility of cadmium(6-8) and the high sensitivity of shoots towards cadmium. The root-barrier effect on lead (6,9-12) prevented it from affecting highly the shoots of the root-treated plants as cadmium did. However, when lead was added directly to shoots in the case of foliar-treatment a high weight reduction of shoots appeared.

Total Uptake of Lead and Cadmium by Treated Carrots

Lead and cadmium uptake of carrots and of their roots and shoots increased with the increase of metal concentration in sulutions used for root-treatment or for foliar-treatment of plants (see Tables 4 and 5).

The results of Table 4 indicated that most of the lead added by root-treatment concentrated in the roots of treated plants (average of 89.2%)while most of the lead added by foliar-treatment concentrated in leaves (average of 95.4%). This confirms the idea that roots act as a barrier against translocation of lead from soil to shoots in the case of

Table (4)

Lead Content of Carrot Plants Treated with Lead

Pb conc in solutions used for treatment (ppm)	Roots µg	%	Shoots µg	%	Whole plant µg	%
Root-Treatment (200ml×12times)						
0.0	0.071	58.9	0.049	41.1	0.120	100
0.6	2.431	91.7	0.220	8.3	2.652	100
1.9	2.814	89.0	0.348	11.0	3.162	100
3.1	4.158	94.8	0.227	5.3	4.385	100
6.3	4.530	89.1	0.555	10.9	5.094	100
9.4	5.086	89.3	0.643	10 7	6.029	100
12.5	5.970	86.8	0.910	13.2	6.880	100
18.8	6 063	83.6	1.194	16.6	7.257	100
Foliar-Treatment (50ml×12times)						
0.0	0.071	58.9	0.049	41.1	0.120	100
0.6	0.273	5.7	4.550	94.3	4.823	100
1.9	0.315	9.6	6.480	95.4	6.795	100
3.1	0.442	3.2	13.210	96.8	13.652	100
6.3	0.525	2.4	21.201	97.6	21.725	100
9.4	0.612	6.1	9.431	93.9	10.043	100
12.5	0.910	6.1	14.630	94.1	15.540	100
18.8	0.640	4.1	15.070	95.9	15.719	100

Table (5)

Cadimum Content of Carrot Plants Treated with Cadmium

Cd conc. in solns. used in treatment (ppm)	Roots µg	Roots %	Shoots µg	Shoots %	Whole plant µg	Whole plant %
Root-Treatment (200ml x 12 times)						
0.0	0.022	42.4	0.030	57.6	0.0528	100
0.4	0.270	67.8	0.128	32.2	0 398	100
1.1	1.140	81.4	0.261	18.6	1.401	100
1.8	4.700	76.6	1.440	23.5	6.140	100
3.6	0.378	21.5	1.377	78.5	1.755	100
5.5	0.908	6.4	13.190	93.6	14.098	100
7.3	1.630	22.2	5.702	77.8	7.330	100
10.9	3.220	30.3	7.400	69.7	10.620	100
Foliar-Treatment (50 ml x 12 times)						
0.0	0.022	42.4	0.030	57.6	0.052	100
0.4	0.160	13.3	1.040	86.7	1.200	100
1.1	0.409	24.4	1.270	75.6	1.679	100
1.8	0.683	23.7	2.170	76.1	2.853	100
3.6	0.520	7.9	6.060	92.1	6.580	100
5.5	2.050	17.3	9.803	82.7	11.850	100
7.3	4.280	27.3	11.420	72.7	15.702	100
10.9	3.401	10.6	14.900	81.4	18.301	100

root-treatment or from shoots into soil in the case of foliar-treatment.

Results of Table 5 indicated that cadmuim was concentrated more in the shoots than in the roots of plants treated with either root-treatment (with the exception of the very low concentrations,<2ppm, of cadmuim) or foliar-treatment (all concentrations). However, the percentage of cadmuim in shoots, in both cases,was not as high as in the case of lead. Ihis is again consistent with the higher mobility of cadmium in plant than lead In all cases, only a very small amount (< 1.5%) of the lead or cadmium added during treatment of plants was taken by plant (c.f. Iable 6). Values of Table 6 showed also that the percentage of uptake from the total amount of metal added decreased with the increase of lead or cadmium concentration in solutions used for treatment of plant.This percentage was also comparatively higher from lead than from cadmium and higher in case of foliar-treatment than in case of root-treatment by either lead or cadmium.

Concentration of Lead and Cadmium in Treated Plants

Concentration of lead and cadmium (shown in Tables 7 and 8) increased in treated carrot plants and in their shoots and roots with the increase of lead and cadmium in solutions used for root-treatment or foliar-treatment of plants. The increase of lead concentration was more obvious in the roots in case of root-treatment (average concentration in roots ~9 times that in shoots) and in the shoots in case of foliar-treatment (average concentration in shoots ~ 35 times that in

Table (6)

Percentage of Metal Taken by Plant from the Total Amount of Metal Ions Added During Treatment of Plant

Concentration in solutions used for treatment (ppm)	Root-treatment		Foliar-treatment	
	Lead	Cadmium	Lead	Cadmium
0.4	--	0.04	--	0.48
0 6	0.18	--	1.31	--
1.1	--	0.05	--	0.25
1.8	--	0.14	--	0.26
1.9	0.07	--	0.59	--
3.1	0.06	--	0.73	--
3.6	--	0.02	--	0 30
5.5	--	0.11	--	0.36
6.3	0.03	--	0.57	--
7.3	--	0.04	--	0.35
9.4	0.03	--	0.18	--
10.9	--	0 04	--	0.28
12 5	0.02	--	0.21	--
18.8	0 02	--	0.14	--

roots). The increase of cadmium concentration (c.f. Table 8) was more obvious in the shoots in both types of treatment (average concentration in shoots was ~5 times that in roots in case of root-treatment and ~9 times that in roots in case of foliar-treatment).

Table (7)

Lead Concentration of Carrot Plants Treated with Lead

Pb conc. in solns. used for treatment (ppm)	Roots (µg/g) (ppm)	Shoots (µg/g)	Whole plant (µg Pb/g dry plant)
Root-Treatment (200ml x 12 times)			
0.0	0.057	0.049	0.054
0.6	2.683	0.275	1.555
1.9	3.434	0.562	2.196
3.1	4.962	0.283	2.675
6.3	6.724	0.904	3.952
9.4	13.008	1.310	6.994
12.5	18.656	2.264	9.529
18.8	21.199	2.132	8.578
Foliar-Treatment (50ml x 12 times)			
0.0	0.057	0.049	0.054
0.6	0.237	4.784	2.299
1.9	0.319	8.100	3.800
3.1	0.498	19.090	8.641
6.3	0.731	33.760	16.140
9.4	0.788	19.247	7.927
12.5	1.429	39.182	13.656
18.8	1.045	72.105	18.870

Table (8)

Cadmium Concentration in Carrot Plants Treated with Cadmium

Cd conc. in solns. used for treatment (ppm)	Roots (µg/g)	Shoots (µg/g)	Whole plant (µg Cd/g dry plant)
Root-Treatment (200ml x 12 times)			
0.0	0.018	0.030	0.024
0.4	0.243	0.156	0.206
1.1	1.106	0.327	0.787
1.8	4.855	2.149	3.748
3.6	0.528	2.086	1.275
5.5	1.726	25.268	13.452
7.3	3.189	18.881	9.016
10.9	7.156	35.407	16.115
Foliar-Treatment (50mlx12times)			
0.0	0.018	0.030	0.024
0.4	0.139	1.101	0.573
1.1	0.352	1.735	0.887
1.8	0.702	3.500	1.792
3.6	0.565	11.264	4.516
5.5	3.553	20.129	11.137
7.3	9.304	35.466	20.028
10.9	8.439	74.129	30.300

CONCLUSIONS

Presence of lead and cadmium in irrigation water or in air (deposited later with rain water) was proved to be very harmful to the growth of carrots.

Root-treatment of carrot plants with lead solutions (0.6-18 18 ppm, repeated for 12 times over the whole period of growth) resulted in 24-62% weight reduction. Foliar-treatment was more harmful on the growth of carrots than root-treatment Treatment with lead using the same concentrations used in root-treatment but with one fourth the total amount resulted in 6-63% weight reduction of treated plant. Effect of root-treatment with lead was higher on roots while foliar-treatment was more effective on the shoots of the treated plants.

Root-treatment with cadmium solutions (0.4-10.9 ppm , repeated for 12 times over the whole period of growth) resulted in 14-71% weight reduction of treated plants. Foliar-treatment using the same concentrations but one fourth the amount of cadmium used in root-treatment resulted in 6-73% weight reduction of treated plants. This indicated a higher effect of foliar-treatment with cadmium than root-treatment. The effect of both types of treatment with cadmium was higher on shoots than on the roots of the treated plants.

The results of 50% weight inhibition indicated that cadmium was more toxic on the growth of carrots. This was more obvious with foliar-treatments. The results might be

explained considering the higher mobility of cadmium than lead in plant and the more sensitivity of shoots than roots towards cadmium.

Concentration and total content of lead and cadmium in treated carrots as well as in their roots and shoots increased with the increase of concentration of metal ions in solutions used for either root-treatment or foliar-treatment of plant. Most of the lead (~90%)taken by plant in case of root-treatment was concentrated in roots while most of the lead added in case of foliar-treatment (~95%)was concentrated in the shoots of the treated plants. Most of the cadmium taken by plants in both types of treatment was concentrated in the shoots of the treated plants with the exception of root-treatment using very low concentrations of cadmium (<2ppm) where cadmium was more concentrated in the roots of the treated plants. However,the degree of polarity of cadmium concentration in plant in both types of treatment was less than the degree of polarity of concentration of lead . There were indications of higher mobility of cadmium than of lead.

Calculations revealed that only a very small part (< 1.5%) of the lead or cadmium added during treatment of plant was concentrated in the plant tissues.Ihis part was higher from lead than from cadmium and higher in foliar treated plants than in root-treated plants and from low concentrations than from higher concentrations of lead or cadmium in solutions used for treatment of plant.

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